

Current NASA Icing Research Overview

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OUTLINE



- Workshop Goals and Objectives
- NASA's Current Aircraft Icing Research Effort

Workshop Goals and Objectives



NASA's future icing research primarily requires addressing icing hazards associated with advanced air vehicles that NASA is developing with partners. With this approach assisting the current needs of the external icing communities is also expected to occur.



Workshop will:

- Solicit input from industry and other government agencies for the identification of possible icing hazards associated with advanced air vehicle configurations and concepts including transport category, rotorcraft and unmanned aerial vehicles.
 - Primary emphasis is transport category but would like to capture inputs on rotorcraft and UAVs.
 - Rotorcraft and UAVs may warrant separate workshops at the direction of NASA senior management
- Results of the workshop will be used to plan icing research to be conducted by the NASA Aeronautics Research Mission Directorate beginning in fiscal year 2016 and run nominally 5 years.
 - The workshop will begin with an overview session in which NASA will present current icing research and advanced air vehicle configurations including transport category, rotorcraft and unmanned aerial vehicle concepts and configurations.
 - Following the overview presentations, the workshop will transition into facilitated breakout groups centered on identification of icing hazards to engines, airframe, and engine/airframe integrations.
 - Minutes of each session will be captured and reported at the closing session on the second day. The icing hazards breakout groups are likely to be related to the engine, the airframe, and engine/airframe integration.
 - We believe that your direct participation in the workshop will add value to the overall icing research planning process

Historical Project Goals and Objectives



Objective: The Atmospheric Environment Safety Technologies (AEST) Project will investigate sources of risk and provide technology needed to help **ensure safe flight in and around atmospheric hazards.**

Focus: In-flight icing, both engine and airframe. Research will also include investigations of other high priority atmospheric hazards and sensor technologies required for their detection.

Relevance to National Needs

1. Engine icing incidents are occurring on a frequent basis with the aviation community calling for action
2. New aviation regulatory requirements necessitate the development new and enhanced icing simulation tools
3. Operations in the Next Generation Air Transportation System environment demand precise information about the atmosphere and awareness of weather hazards
4. More composite aircraft (i.e. B777 (20% composite, 1995 service), B787 (50% composite, 2011 service)) requiring protection from structural and avionic lightning damage



Linkages to Program Goal

“Proactively identify, research, develop and mature tools, methods, and technologies for improving overall aircraft safety of new and legacy vehicles operating in the Next Generation Air Transportation System.” – AvSP Program Plan

Summary of Project's Technical Challenges (TC)



- **Engine Icing Characterization and Simulation Capability:**
Develop knowledge bases, analysis methods, and simulation tools needed to address the problem of engine icing; in particular, ice-crystal icing
- **Airframe Icing Simulation and Engineering Tool Capability:** Develop and demonstrate capability to simulate and model airframe ice accretion and related aerodynamic performance degradation for current and future aircraft configurations in an expanded icing environment that includes freezing drizzle/rain
- **Atmospheric Hazard Sensing and Mitigation Technology Capability:** Improve and expand remote sensing capabilities for atmospheric hazards to provide warning, hazard measurement, and mitigation; mitigate lightning strike damage to composite aircraft by strike protection systems development



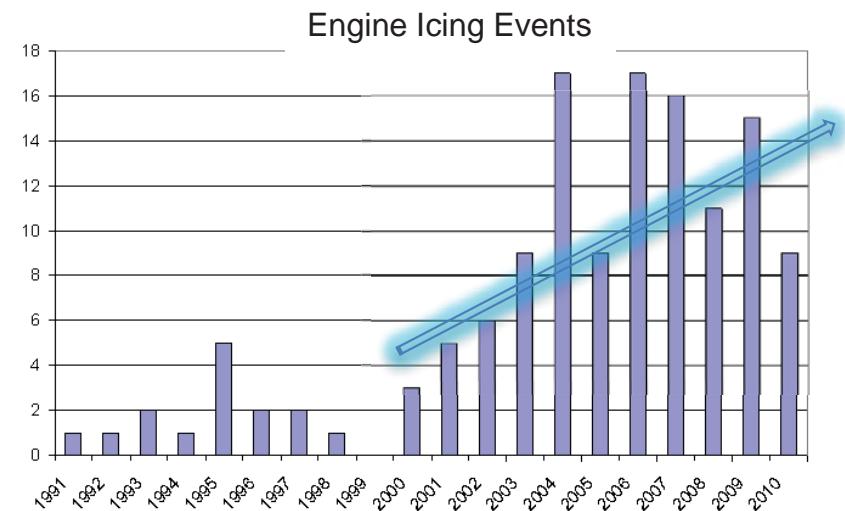
Technical Challenge (Engine Icing)

Engine Icing Characterization and Simulation Capability: Develop knowledge bases, analysis methods, and simulation tools needed to address the problem of engine icing; in particular, ice-crystal icing

Goal: *Eliminate turbofan engine interruptions, failures, and damage due to flight in high ice-crystal water content (HIWC) clouds*

Benefit: *Verified basis for engine icing certification requirements; enable new engine icing protection systems and methods*

Benefit Domain: *All turbofan/turbojet powered aircraft; engine manufacturers, aviation system regulators, and pilots and operators*



From Mason & Gryzch, "The Challenges Identifying Weather Associated With Jet Engine Ice Crystal Icing", SAE 2011-38-0094, June 2011

Engine Icing Research Approach



**Ice Accretion
Physics**



**Computational
Tools**



**Experimental
Methods**



**Atmospheric
Characterization**



**Engineering
Solutions**

*Engine Icing
Accretion and
Performance Tools*

*Means/Basis of
Engine
Certification
Compliance*

*Engine Icing Test
Methodologies*

*Scaling
Laws/Transfer
Functions from
Altitude to Sea
Level*

Technical Challenge (Airframe Icing)



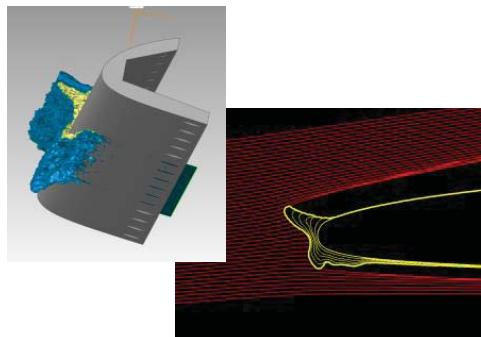
Airframe Icing Simulation and Engineering Tool Capability: Develop and demonstrate capability to simulate and model airframe ice accretion and related aerodynamic performance degradation for current and future aircraft configurations in an expanded icing environment that includes freezing drizzle/rain

Goal: Achieve acceptance of simulation tools for design and certification of swept wing configurations over an expanded range of icing conditions

Benefit: Enable aircraft manufacturers to perform reliable icing assessments and build in effective icing mitigation approaches for current and future aircraft; development of technology that enables safe flight operations in an super-cooled large droplet environment

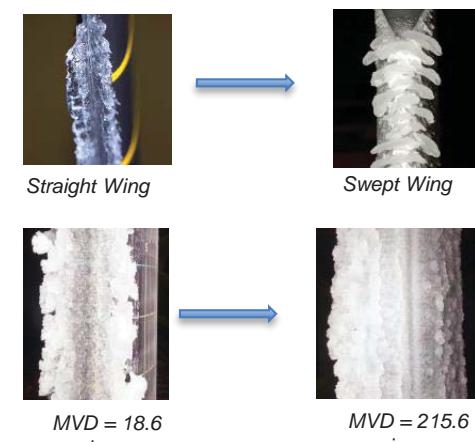
Benefit Domain: Aircraft and aircraft sub-system manufacturers and aviation system regulators

Appendix C Standard (Super Cooled Smaller Droplets) and Straight Wing (2-D) Icing



Current NASA Icing Simulation Tools Well Validated and Accepted by Aviation Community

Appendix O Standard (Super-Cooled Larger Droplets) and Swept Wing (3-D) Icing



Expanding Current Icing Simulation Tools to Swept Wing and Freezing Rain/Drizzle Icing

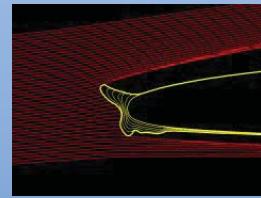
Airframe Icing Research Approach



**Ice Accretion
Physics**



**Computational
Tools**



**Experimental
Methods**



**Ice Protection
System (IPS)
Modeling**



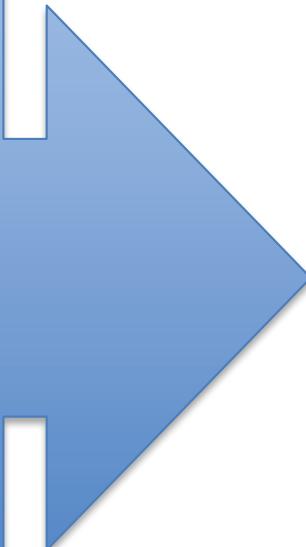
**Engineering
Solutions**

*Airframe Icing
Accretion and Aero
Performance Tools*

*Means of Airframe
Icing Certification
Compliance*

*Airframe Icing Test
Methodologies*

*Thermal Scaling
Laws/Transfer
Functions from
Altitude to Sea
Level for IPS*



Technical Challenge (Atmospheric Hazard Sensing and Mitigation)



Atmospheric Hazard Sensing & Mitigation Technology Capability: Improve and expand remote sensing capabilities for atmospheric hazards to provide warning, hazard measurement, and mitigation; mitigate lightning strike damage to composite aircraft by strike protection systems development

Goal: *Mature technologies for sensing and measurement of icing, turbulence, and wake vortex hazards for real-time information to the pilot and operators in the NAS and to address low visibility conditions for safer runway operations; develop technologies for a lightning immune composite aircraft*

Benefit: *Greater ability for aircraft to avoid hazards; hazard information available for sharing with other aircraft and ground-based systems; reduced vulnerability to lightning and other hazards*

Benefit Domain: *All aircraft flying in the NAS; pilots, operators, and controllers*

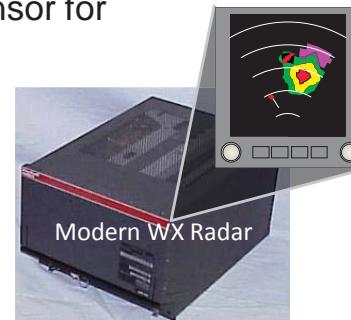


Technical Challenge (Atmospheric Hazard Sensing and Mitigation)

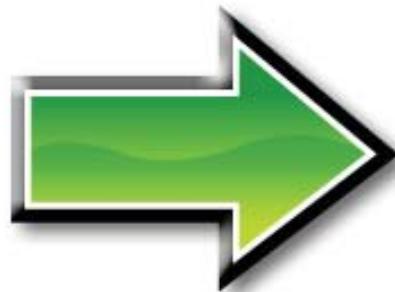


State-of-the-Art

- Weather radar is currently the only common remote sensor for atmospheric hazards on commercial aircraft. Sensing capabilities are limited by old designs and apps and not the technology.



- Modern weather radar can detect
 - Severe Wx
 - Windshear
 - Convective Turbulence
- Off-board hazard information, when it is available, is provided to the aircraft by voice or text. This information is often sparse, inaccurate, or non-specific.
- Known and potential weather hazards are avoided with large, conservative margins for safety, due to high uncertainties.



Future of Atmospheric Hazard Detection

Improved and Expanded Remote Sensing of Hazardous Atmospheric Environments



High Altitude Ice Crystals



Clear Air Turbulence



Wake Vortex



Icing



Low Visibility Conditions

Better hazard and weather information in the cockpit and available for download to other users

Advanced sensor technologies employed to increase variety of hazards detected, improve situation awareness, and mitigate hazard effects ¹¹

Atmospheric Hazard Sensing and Mitigation Research Approach



Icing Weather Systems



Advanced Radar



Lidar Electro-Optical Sensors



Smart Visual Awareness



Lightning Sensing-Composite Aircraft



Engineering Solutions

Algorithms for ground-based sensors that supports the FAA Terminal Area Icing Weather Information for NextGen (TAIWIN)

Develop sensor technologies to provide new hazard detection and measurement capability with practical, economic and effective systems.

Measure and understand lightning strike characteristics and develop new lightning strike protection for composite aircraft that uses wireless sensors capable of measuring lightning strike severity, location, and damage.

Tech Challenge Relevance



- Engine Icing
 - Strong financial and in-kind support from FAA, Boeing, National Research Council of Canada, Environment Canada, European High Altitude Ice Crystal Consortium, Australia Bureau of Meteorology, Honeywell
 - Community interaction maintained by signed agreements, participation in related working groups and conferences
- Airframe Icing
 - Strong financial and in-kind support from FAA, ONERA (France), INTA (Spain) and Boeing
 - Heavy involvement in NASA Research Announcements (NRAs)
 - Community interaction maintained by signed agreements, participation in related working groups and conferences
- Atmospheric Hazard Sensing and Mitigation
 - Heavy involvement in NASA Research Announcements (NRAs), SBIRs, Honeywell, and the Boeing Company.
 - Community interaction maintained by participation in related working groups and conferences

Project Content Close-Outs



Current Atmospheric Environment Safety Technologies (AEST) Project Product Portfolio

1. Engine Icing Performance Simulation Tool
2. Engine Icing Accretion Simulation Tools
3. Swept Wing Ice Accretion Simulation Tools
4. Supercooled Large Droplet Ice Accretion Simulation Tools
5. Ice Protection System Modeling
6. Advanced Weather Radar
7. Icing Weather Systems for Terminal Area Detection of Icing Conditions
8. Advanced Lidar
9. Smart Avionics Imaging Sensor System
10. Lightning Protection and Detection System for Composite Aircraft

Products to be Reconsidered in Restructured ARMD

1. Engine Icing Performance Simulation Tool
2. Engine Icing Accretion Simulation Tools
3. Swept Wing Ice Accretion Simulation Tools
4. Supercooled Large Droplet Ice Accretion Simulation Tools
5. Ice Protection System Modeling
6. Advanced Weather Radar (**HIWC Only**)

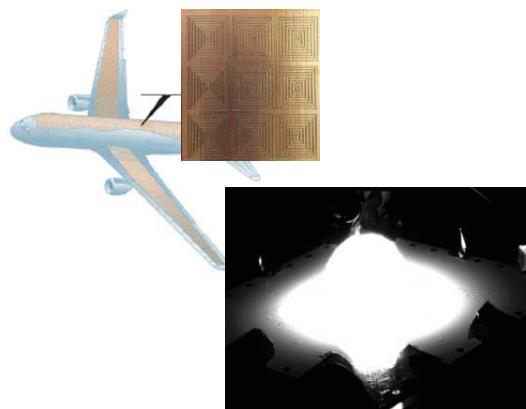
Products to be Phased Out Due to New ARMD Direction

6. Advanced Weather Radar (**end non-HIWC portion in FY14**)
7. Icing Weather Systems for Terminal Area Detection of Icing Conditions (**phase out by mid-FY16**)
8. Advanced Lidar (**end in FY14**)
9. Smart Avionics Imaging Sensor System (**end in FY14**)
10. Lightning Protection and Detection System for Composite Aircraft (**end in FY15**)

Perform 6-9 month study on safety infusion required of advanced aircraft concepts

Redirection of Icing and other Safety resources to relevant Projects to perform needed safety research (not necessarily just icing)

Summary



- Icing project activities have made tremendous progress in FY14 and hopes to continue this progress in the future
 - HAIC-HIWC Flight Campaign in Darwin, Australia successfully achieved with next flight planned for South America in 2015
 - Recovery plan in place to obtain HIWC radar flight data starting in August 2015 in Puerto Rico
 - Ground-based full scale engine icing test facility capability being used by other engine manufacturers with data being shared to NASA
 - Engine ice accretion and performance tools maturing
 - Swept wing and SLD icing simulation tools maturing
 - Lightning mitigation and remote weather sensor technologies maturing
 - NASA Twin Otter aircraft being readied for remote ice sensing flight campaigns in FY15
- Future NASA icing activities need to directly contribute and enable safe operations of future advance aircraft configurations
- This Workshop will enable the planning team to focus on the right research icing areas